Stated Meeting, May 19, 1865.

Present seventeen members.

President, Dr. WOOD, in the chair.

Letters of envoi were received from Herr Von Limburg, Consul of the Netherlands, dated New York, March 5, and from the Secretary of the San Fernando Academy, dated Madrid, Dec. 28, 1864.

Letters of acknowledgment for the receipt of copies of the Transactions and Proceedings, were received from the following, Academies, Societies and Public Offices:—

Vol. IX, i, ii, XII, i, from the Central Physical Observatory of Russia, Dec. 2, 1863.
Vol. XII, iii, from the Dublin Geological Society, April, 16, 1864.
Vol. XII, iii, from the R. Society, Edinburgh, Jan. 4, 1865.
Vol. XIII, i, from Prof. Loomis, of Yale College, May 4, 1865.
Vol. XIII, i, from Harvard College, April 15, 1865.
Vol. XIII, i, from Boston Academy of Science, April 14, 1865.
Vol. XIII, i, from Lyceum N. H., New York, May 15, 1865.
Vol. XIII, i, from Dr. D. H. Storer, of Boston, April 13, 1865.
Vol. XIII, i, from the Astor Library, New York, April 18, 1865.
Vol. XIII, i, from Penn. Hist. Society, May 11, 1865.
Vol. XIII, i, from Library of Congress, May 3, 1865.
Vol. XIII, i, from Dr. C. M. Wetherill, April 18, 1865.
Catalogue, Part 1, from the Belgian Academy, Sept. 5, 1863.
Nos. 28 to 31–34, from Central Obs., Russia, Dec. 1863.
Nos. 61 to 66, from Central Obs., Russia, Dec. 1862.
No. 62 and title to VIII, from Prussian Academy, Nov. 30, 1864.
Nos. 68, 69, 70, from the Geological Society, Dublin, April, 1864.
Nos. 69, 70, from the Royal Society, Edinburgh, January, 1864.
No. 69, from the Royal Asiatic Society, Dec. 7, 1863.
No. 69, from the Royal Society at Göttingen, 1863.
No. 70, from the Geographical Society, Paris, Sept. 1, 1864.
No. 70, K. K. Geological Institute, Vienna, Sept. 26, 1864.
No. 70, Wm. Haidinger, of Vienna, Sept. 26, 1864.
No. 70, from Lyceum N. H., New York, March 27, 1865.
No. 70, from Zoological Society, Frankfort, A. M., Dec. 20, 1864.
No. 70, from Royal Academy at Bruxelles, Dec. 18, 1864.

No. 71, from Smithsonian Institution, Oct. 22, 1864.
No. 72 and List, from University of Toronto, March 23, 1865.
No. 72 and List, from Amherst College, March 21, 1865.
No. 72 and List, from Harvard College, March 20, 1865.
No. 72 and List, from Massachusetts Hist. Society, March 23, 1865.
No. 72 and List, from Boston Library, March 21, 1865.
No. 72 and List, from Lyceum N. H., New York, March 20, 1865.
No. 72 and List, from George Bancroft, April 13, 1865.
No. 72 and List, from Yale College, April 12, 1865.
No. 72 and List, from Boston Academy, April 14, 1865.
No. 72 and List, from Astor Library, April 18, 1865.
No. 72 and List, from Maryland Historical Society, April 5, 1865.
No. 72 and List, from Chicago Historical Society, March 30, 1865.
No. 72 and List, from Dr. C. M. Wetherill, April 18, 1865.

A photograph of Dr. Augustus A. Gould was presented as a donation for the Album.

Donations for the Library were received from the Observatory at Cadiz, the Academy San Fernando at Madrid, the Geological Survey of Holland, the Museum at Cambridge, the Franklin Institute, the Historical Society at Philadelphia, and the Mercantile Library Association at San Francisco.

Prof. Cresson communicated his observations of the effects of the late destructive tornado, or series of tornadoes, which swept with such velocity and violence across Eastern Pennsylvania and New Jersey, in the afternoon of Thursday, the 11th instant, where he saw them along the line of railroad between Hackettstown and Hoboken.

All the trees seem to have been overthrown in a direction contrary to the course of the storm-wind, viz., with their heads towards the west. Mr. Trego described the storm as he knew of it in Pennsylvania, north of Philadelphia, and as far as New Hope, on the Delaware. Mr. Price described its ravages further west, accompanied as it was with much hail. Mr. Haldeman described it on the Susquehanna River, where it was also a hail-storm, and gave evidence to show that it originated on this side of the Alleghany Mountains. It seems to have traversed the whole space from Lan-

caster County to the neighborhood of the Hudson and the Atlantic shore in an hour or so.

Mr. Briggs gave a description of his recent visit to the Venango County Oil Region.

He described the discomforts of travelling to it, the crowds which filled it, the muddiness and general disorder which characterizes it, the reckless waste of money, time, and energy, manifest throughout it; the smallness of the average production of oil for the outlay, and, in his opinion, the entire absence of all reliable geological indicia for determining a good place for boring. He described minutely the method of constructing the derricks and boring machinery, and of using the tools in the process of boring, each of which he named, described, and exhibited in drawings, expressing his admiration of the practical tact which had been developed, the perfect adaptation of simple means to the desired end, and the rapidity and precision with which wells are sunk every day, which a few years ago would have been considered triumphs of the best engineering ability in Europe. The history, progress, and detailed method of each single Artesian well were, but a few years ago, considered worthy of elaborate illustrated publication. Now, in his opinion, at least two hundred such wells are being sunk all the time, with a simplicity of apparatus, and a speed and certainty of progress, which, although unrecorded, throws all former exhibitions of skill into the shade.

The daily present amount of petroleum reaching the depot of Oil City is about four thousand barrels, while not less than three thousand wells are in various stages of action in that part of the Oil Creek Valley, and those of its branches which lie within easy reach of Oil City. Of this amount, three thousand barrels are the production of a few large wells, leaving an average of say one-third or one-fourth of a barrel per day to the remainder; of this last number, he thinks not more than one well in twenty produces anything at all.

Mr. Briggs described, in addition to his former remarks, his visit to the Parkersburg region in Virginia, and the single instance which fell under his observation of a truly economical application of power by a company established twelve or fourteen years ago, whose numerous wells were all sunk and pumped by one engine, by means of horizontal rods led off from it in different directions between pairs of fence posts, from the caps of which swinging arms were hung,

the whole arrangement being used also for farming purposes, to serve as common field fences.

Mr. Lesley agreed with Mr. Briggs as to the total absence of all practical surface indications of a strictly local kind, available in even the slightest degree for determining the position of any well; and also in the opinion which Mr. Briggs expressed that the upland is as good oil-boring territory as the valley bottoms, the necessary addition to the depth of the well being of no practical importance.

He described and objected to such sections of the valley as that recently published in the Oil Region Atlas, and to the whole theory of valley-bed subsidence, faulty structure of the foot of the valley-walls, disturbed condition of oil regions, and other popular notions of surface disorder, considered as indications of the goodness of boring localities. He referred to the privately expressed opinion of a distinguished geologist, that the petroleum was pressed towards the valleys by the weight of the upland on each side, where the action had cracked the valley bed in the style of a floor-creep in a coal drift, and showed that it was improbable on the mechanical theory of the reversed arch.

He described the three great conditions for oil; first, an abundance of organic remains; secondly, a permeable and yet compact sandy or gravelly horizontal oil reservoir; and thirdly, a system of vertical oil reservoirs or open cleavage-planes, in polar directions, but confined to single formations, and having nothing whatever in common with the great faults which penetrate the earth crust in disturbed districts. He concluded that the general geological characteristics of an oil region were as fixed and reliable as the local surface indications were the contrary. He took the liberty of describing the yet little understood theory of M. Lesquereux (who had been prevented by circumstances from sending a memoir on the subject, to be read at this meeting), consisting essentially in the distinction between the genesis of coal from woody fibre, and the genesis of petroleum from non-fibrous vegetation, or marine fucus; and said that the Society might hope soon to have the explanation of this generalization in all its bearings from the eminent botanist who has done so much for the elucidation of the geology of the coal measures.

Mr. Chase described his late visit to some wells in Southern Pennsylvania, and showed how ignorantly the popular notion of three sandrocks was carried from the Venango to other and distant regions, and applied absurdly to a different geological condition of things.

Mr. Chase made a communication on the correlation of gravity with the vertical deflection of the needle.

A somewhat critical survey of the anomalies presented by the magnetic inclination, to which I referred in a former article (Proc. Am. Phil. Soc., April 21, 1865), has given me renewed reasons for regretting the want of a complete record of the investigations on which Prof. Secchi based his conclusion, that *all* "the phenomena hitherto known of the diurnal magnetic variations may be explained by supposing that the sun acts upon the earth as a very powerful magnet at a great distance."* As I know of no magnetic law which will account for those anomalies, I propose briefly to describe them, and to point out some relations between the gravitation currents and the *dip* of the needle, as a sequel to my papers on the influence of gravity upon the total magnetic force and the magnetic declination.

Gen. Sabine's discussions have shown some important points of difference between the magnetic disturbances at inter-tropical and extra-tropical stations, the Cape of Good Hope being magnetically, though not geographically, inter-tropical. In the third volume of the Toronto Observations, and in Prof. Bache's discussions of the observations at Girard College, projections of the daily and semi-annual inclination-curves are given;† and Plate V, of the second volume of the Hobarton Observations, contains a graphical representation of

* Phil. Mag. [4] IX, 452. Faraday (Exp. Res. III, 493) states "that the celebrated Prof. Gazzaniga, starting from his numerous experiments, which demonstrate the influence of magnetism upon the same aerial fluids, in a manner, therefore, different from that of Bancalari, was induced to consider the sun, and all the other celestial bodies, as so many enormous magnets, by which he established that attraction is merely one effect of the magnetism of the great celestial masses placed at an enormous distance,—an idea which reappeared in 1846 in Prussia, and in 1847 in France."

While admitting the intimate relationship of magnetism and gravity, I must dissent from the learned Professor's inference. For the evidence appears irresistible, that the earth's magnetism is directly dependent on the terrestrial gravitation of the thermally disturbed aerial currents, and that it is only slightly affected by the perturbations of solar and lunar gravitation, so that if we regard the relationship as a causal one, magnetism, rather than attraction, should be considered as the effect. (See Gauss' "General Theory of Terrestrial Magnetism," § 39, 40; Taylor's Scientific Memoirs, II, 232.)

† By the kindness of Prof. Henry, I have been permitted to refer to the proof-sheets of the Fourth Section of Prof. Bache's Discussions.

the diurnal variations of the inclination at the different observation hours in the four seasons. If we also project, from Gen. Sabine's tables of the mean results, the daily and semi-annual curves at St. Helena and Cape Colony, and compare the curves at the five stations, it will be found that,

1. The greatest daily disturbance of inclination occurs about noon.

2. At (magnetically) inter-tropical stations, the dip is diminished, but at extra-tropical stations it is increased in the middle of the day.

3. Increasing temperature and increasing solar altitude augment the inclination disturbance. This is shown both by the diurnal and the semi-annual curves.

4. As a corollary of propositions 2 and 3, at St. Helena and Cape of Good Hope, the inclination-disturbance is opposed to, and subtracted from the normal dip; but at Philadelphia, Toronto, and Hobarton the disturbance is added to the dip. Thus the inclination is

a MINIMUM	at	St. Helena,	at 22—23 h.
" "	"	Cape of Good Hope,	" 0— 1 h.
" MAXIMUM	"	Philadelphia,	" 22— 0 h.
" "	"	Toronto,	" 22—23 h.
" "	"	Hobarton,	" 23— 1 h.

Reasoning either *a priori*, or from Secchi's postulates, we might naturally infer that the ellipticity of the atmosphere would be increased by the direct action of the sun, and that, consequently, from the tendency of magnetic parallelism to the gravitation currents, the dip would be augmented at noon in all places between the magnetic equator and the magnetic poles.

Mr. William Ferrel, in his paper* which furnished the first satisfactory explanation of the barometric depression at the equator and at the poles, shows that in consequence of the earth's motion fluids tend to assume a form similar to his Fig. 1 (Math. Monthly, I, 215), "*the surface of the fluid being slightly depressed at the equator, having its maximum height about the parallel of* 35°, *and meeting the surface of the earth towards the poles.*" The direct action of the sun, in increasing the equatorial ellipticity of the air, may also increase the tendency to equatorial and polar depression, and the magnetic parallelism may, therefore, be manifested in the solar-diurnal inclination-disturbance *precisely as it is manifested* at St. Helena

* "The motions of fluids and solids relative to the earth's surface." See Nashville Journal of Medicine and Surgery for 1856, and Mathematical Monthly for 1859, I, 140, sqq.

and Cape of Good Hope, by a diminution of dip between the parallels of 35°, and an increase in higher latitudes.

These coincidences may well suggest the need of more extensive observations in different parts of South America, Northern Africa, Southern Asia, the Pacific Ocean, and the Frigid Zones, to furnish the data for determining to what extent mountain ranges, coast lines, land and water radiation, winds, and ocean currents modify the theoretical phenomena of dip and declination.

By projecting on isoclinal and isogonic charts* the magnetic currents as indicated by the position of the needle in different portions of the globe, I have obtained the following results, which serve to show the character of some of these modifications:

I. Declination.

1. The currents manifest a tendency to follow the lines of most direct ocean communication between the warmest and the coldest portions of the globe, the general declination being westerly in the Atlantic, and easterly in the Pacific Ocean.

2. The lines of no variation are apparently determined in part by the land contours† that divide the waters of the globe into two great bodies.

3. The currents are deflected by the southern pointed extremities of the several continents, towards the east on the eastern shores, and towards the west on the western shores of New Holland, Africa, and South America.

4. The magnetic currents, in the three respects above enumerated, exhibit *a precise parallelism to the ocean tidal flow.*

5. In the comparatively narrow belt of the Atlantic Ocean, the declination between the parallels of 35° reaches 30°; in the broad expanse of the Pacific, the maximum within the same limits of latitude is 15°.

6. Between the parallels of 70° and 80° the declination becomes

* The charts that I used, were the polyconic projection of the "Lines of equal magnetic variation for the year 1858," which was constructed from Evans's English Admiralty Chart, for the United States Coast Survey Report of 1859, and No. 1 and 2 of the "Admiralty Manual for ascertaining and applying the deviations of the compass caused by the iron in a ship." 2d edition, 1863.

† The influence of coast lines in producing a tendency to equality of declination, is beautifully shown in the United States Coast Survey Chart of "Lines of equal magnetic declination on the Gulf of Mexico for the epoch 1860.0."

very great, and the currents tend to a gyratory or cyclonic motion, which appears to be modified by glaciers or local poles of great cold.

7. The cyclonic tendency is most marked in the southern hemisphere, where the ocean waters experience the least interruption to their normal motions. Mr. Ferrel's computation gives "28° 30′ for the polar distance of the parallel where the surface of the fluid, or the stratum of equal pressure, meets the surface of the earth."* It will be readily seen that at that distance the south pole is entirely surrounded by water, and it seems, therefore, highly probable, that if there were no land in the frigid zones, there would be no definite magnetic poles, but a simple polar belt towards which the magnetic currents would flow in parallel spirals,† except when deflected by land radiation, or tidal or other gravitation currents.

II. Dip.

8. The lines of equal dip are arranged in approximate parallels, around the two (principal) magnetic poles.

9. In consequence of this parallelism, they are convex towards the north in the Pacific Ocean, and towards the south in the Atlantic Ocean.

10. The magnetic parallels also approximate to the isothermal parallels, both in direction and in position, but with some important departures.

11. In South America, the magnetic equator is depressed nearly 30° south of the isothermal equator; it is, however, nearly equidistant from the (principal) north and south magnetic poles.

12. The magnetic parallels near the magnetic poles, are more convex than the isothermal lines, but they present some interesting instances of parallelism to the ocean currents, which are indisputably gravitation currents.

13. This parallelism is specially observable in the regions of the equatorial currents, the Gulf Stream, and the North Pacific and Japan currents.

14. If a series of waves were propagated through the air, from the magnetic poles to the equator, with slight deflections by the continental contours and ocean currents, they could be represented with great accuracy by the magnetic parallels.

All of the foregoing modifications, as well as the theoretical phenomena previously referred to, have their exact counterparts in the

* Loc. citat.

† This inference accords with Barlow's conclusion that every place has its particular polarizing axis.

currents which tend to restore the gravitation equilibrium of the air and water. It may be unwise, ignorant as we are of the true nature of causal efficiency, to assert that one form of force is produced by another, but it is one of the most important duties of true philosophy, to observe sequences and correlations. It has long been known that magnetic action may be so directed as either to assist or counteract the attractions of cohesion, chemical affinity, and gravitation; it has also been known that, under certain circumstances, disturbances of chemical or of cohesive attraction are accompanied by magnetical disturbances,* but I have now shown for the first time, by independent examinations of the total force, declination, and dip, that disturbances of gravitation are similarly attended.

It would certainly be very satisfactory, if it were possible, to have some means of exhibiting, by simple laboratory experiments, the direct and mutual convertibility of gravitation and magnetism, but I fear the attempt to reproduce, in any appreciable mechanical form, the magnificent and daily repeated operations in the laboratory of nature which I have feebly endeavored to interpret, must always be futile. In order to obtain even the small amount of disturbance (.00134) which I have noted in the half-daily variation of atmospheric weight (Trans. A. P. S., XIII, 121), it would be necessary to take observations at two stations, one of which should be 2.655†

* "A few years ago magnetism was to us an occult power, affecting only a few bodies; now it is found to influence all bodies, and to possess the most intimate relations with electricity, heat, chemical action, light, crystallization, and, through it, with the forces concerned in cohesion; and we may, in the present state of things, well feel urged to continue our labors, encouraged by the hope of bringing it into a bond of union with gravity itself." *Faraday: Exp. Res.* 2614.

† $R \times (\sqrt{D'} - \sqrt{D}) = 3963 \times (\sqrt{1.00134} - 1) = 2.655$. At Singapore the daily disturbance of total force is only $\frac{3}{4}\frac{1}{3}$ as great as it should be theoretically. I suspect that the discrepancy is owing mainly to the monsoons and other great temperature disturbances of the station, which shift the lines of force by a kind of conduction polarity. (Faraday, Exp. Res. 3279.) In other important respects there is a satisfactory correspondence between Singapore and St Helena. E. g.

	Mean Fall.	Mean Tide. (Theoretical $\times \frac{3}{4}\frac{1}{3}$).		
		0 h.	6 h.	12 h.
Theoretical, . . .	8h. 29′	—.00031	—.000173	+.00064
Observed, . . .	8h. 23′	—.00031	—.000180	+.00064

(See "Numerical Relations of Gravity and Magnetism," Sections V, IX, and Faraday's Experimental Researches, III, 321—2.)

miles more distant from the earth's centre than the other. If the differences of vapor, temperature, barometric pressure, force and direction of wind, atmospheric electricity, &c., did not so complicate the problem as to discourage even the most sanguine experimenter from any attempt at solution, any result that could be obtained under such circumstances would give little general satisfaction.

It is possible, however, that the end, which we should vainly strive to reach directly, may be indirectly attained. Indeed, the various stages of an indirect road have long been known, but we have not been able to compare them by any common measure. The motion of gravity, by percussion or the obstruction of simple fall, has been repeatedly converted into the motion of heat; and the motion of heat, by the thermo-electric pile, has been converted into the motion of magnetism. The experiments of Barlow, Coulomb, Kupffer, and Christie,* on the influence of heat upon the magnet, furnish data that may lend some aid to any investigator who seeks to ascertain the precise value and modification of each force, in these successive conversions.

But I look most hopefully to researches that are based upon differences of specific gravity. Even the experiments of Barlow and others, to which I have just referred, as well as the electro-magnetic currents which are generated by chemical solution, involve such differences; the thermal aerial currents which harmonize with and increase the effects of simple gravitation towards the sun, are caused solely by the greater centripetal tendency of the cold, dense air which has the greatest specific gravity; and the recent investigations in thermo-dynamics, together with the experiments of Fusinieri and Peltier,† confirm the natural conviction that the imponderable agents can only be manifested through their influence on ponderable matter, and, therefore, under tendencies to equilibrium with the force of gravitation. I already find a curious approximate coincidence, to which I attach little importance so long as it is unsupported by corroborative evidence, but I refer to it as an indication of the very character that we might reasonably expect, and one that may possibly become valuable in the course of future research. The last edition of the Encyclopædia Britannica, Article "HEAT," gives for the expansion and consequent diminution of specific gravity between 32° and 212° Fahr., of

Iron, ...	$\frac{1}{819}$
Air, ...	$\frac{3}{8}$

* See Enc. Britan., 8th ed., XIV, 35—39.

† Taylor's Scientific Memoirs, III, 394.

If we suppose their specific magnetisms to be inversely proportioned to the disturbance of their specific gravities, we have, assuming the specific magnetism of iron as the unit,

$$\frac{3}{8} : \frac{1}{819} :: 1 : \frac{1}{307}$$

a value which is intermediate between those given by MM. Becquerel ($\frac{1}{882}$) and Plücker ($\frac{1}{287}$).* This result would be somewhat modified by an accurate determination of the ratios of the linear to the cubic expansions of iron in its several forms.

Faraday disclaims the assumption of any other than a conduction polarity of oxygen (2933, 2934), but that polarity is conveyed in lines strikingly analogous to the thermal gravitation currents (see Exp. Res., 2787, and III, Pl. IV, Fig. 6), which, in their turn, accurately represent the hypothetical indirect action of the sun on the needle, through the atmospheric affection of the lines of force (2936).

I know of no physicist who has given so lucid a theoretical explanation of the various magnetic perturbations, as the illustrious Fullerian Professor, and as his hypotheses appear to me still more satisfactory when viewed in connection with the gravitation disturbances, I will briefly refer to some of the more important points that have helped to confirm me in the various views that I have hitherto advanced. Such are, *e. g.*, the evidences of the identity of helices and magnets (2239); the existence of magnetic repulsion without polarity (2274); the relative magnetic position of gases and vapors (2416); the relations of the magnecrystallic, cohesive, and magnetic forces (2479, 2562, 2578); the probable dependence of the magnetic motions of fluids upon their mass and density (2768, 2769, 2781, 2863); the magnetic influence of winds and varying atmospheric pressure (2952, 2954);† the supposed velocity of magnetic transmission in space or æther (2958); the daily bi-polar minima of cold (3006); the closed circuits and prominent characteristics of the magnetic lines of force (3117, 3278, 3279, 3284); the tendency of all bodies to evolve electric currents, when moving in a magnetic field (3337); the relative diamagnetic and magnetic effects of heat

* Prof. Frazer has kindly referred me to the coefficients of dilatation for iron, in the "Artisan," of Dec. 1, 1860, and to the experiments of Regnault on the dilatation of air (See Jour. of F. Inst. [3], XV, 281). According to these data, the theoretical specific magnetism of oxygen would be between $\frac{1}{294}$ and $\frac{1}{374}$.

† Humboldt speaks of the accumulation of electricity in the lower equinoctial regions, "at the maximum of heat, and when the barometric tides are near their minimum." *Taylor's Scient. Mem.*, III, 398.

and cold upon air and the diamagnetic gases, as well as upon iron, nickel, and cobalt (2861, and III, pp. 446, 460, 464, 472, 473, 489, 490).

It should not be forgotten that there is no such thing within the compass of our observation, as "potential" gravity, no instance of matter in absolute rest, and just beginning or tending to move under a gravitating pull. Every particle of the earth, independently of the action of heat, chemical affinity, and cohesion, is at every instant subjected to four principal and important impulses, two towards the centres of the sun and earth respectively, and two tangential to the earth's orbit, and to its circumference. Of the several motions, the orbital one is by far the most important. Next in point of *velocity* is the one tangential to the circumference,—in point of *intensity*, the one towards the centre of the sun. Since the solar central and tangential motions are in equilibrio, it seems eminently proper that the others should be considered as disturbances, which tend, as I have elsewhere shown, to give a daily ellipticity to each section of air parallel to the equator. Not only are the barometric daily tides a necessary consequence of such ellipticity; owing to the difference of specific gravity, the cold air, in addition to the proper motion of convection, is alternately drawn towards and repelled from the earth's surface; and I am inclined to believe that many of the phenomena of the deposition of dew and the magnetic perturbations, which cannot be explained by other more important gravitation currents, may be thus accounted for.

Mr. Chase offered for publication in the Proceedings a revised list of trade tokens, numbering over two thousand, which, at his request, was referred to a committee of three, consisting of Mr. Peale, Mr. Price, and Mr. Lesley.

The minutes of the Board of Officers and Members in Council at their last stated meeting were read, and on motion of Mr. Peale, the Committee on the Hall was authorized to provide a fire-proof for preserving the most important papers belonging to the Society, at a cost not exceeding three hundred dollars.

Pending nomination No. 540 was read.

And the Society was adjourned.